FINAL REPORT

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The competition of tidal mixing and freshwater forcing in shaping the outflow from Hudson Strait

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Long-Term Goals

The long-term goal of this project was to understand the processes governing the mean structure and variability of the fresh, buoyant current which flows out of Hudson Strait and into the Labrador Sea.

Objectives

1) Investigate the spatial and temporal characteristics of the buoyant plume from moored data including its vertical structure, fresh water content and variability from tidal to interannual time scales from existing moored data in the Strait
2) Identify possible forcings for the variability and develop a theoretical framework linking the forcing with the observed variability

Approach

Subtidal to interannual variability of the fresh water plume was investigated using a combination of moored data, atmospheric reanalysis products and a high resolution regional model of the Hudson Bay System. Tidal variability was examined by comparing the moored data with a global tidal assimilation model, TPXO, run at higher resolution in the Atlantic Ocean and Hudson Bay.

Tasks Completed

- Processing and quality control of the moored measurements and of the McLane Moored Profiler and ADCP data in particular.
- Analysis of the moored data to identify the dominant modes of variability and comparison with both local and remote forcing, as well as with historical data from the upstream Hudson Bay.
- Comparison of the observations with the output from a high resolution, regional numerical model of the Hudson Bay System forced by reanalysis products.
- Comparison of the tidal energy fluxes from the moored data with the TPXO global tidal model of G. Egbert (OSU; http://www.oce.orst.edu/research/po/research/tide)

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14. ABSTRACT
Freshwater discharge in narrow, surface trapped, boundary plumes is a common feature of many coastal areas and straits, especially in the high latitudes. Such plumes have typically been described with synoptic measurements or steady state theoretical models and little is know about their variability or the factors which may influence it. Here we take advantage of there years of moored data across the outflow from Hudson Strait, which transport a large volume of riverine fresh water from Hudson Bay to the Labrador Sea, to investigate the tidal to interannual variability in the export and its forcings. Our analysis shows that the outflow is seasonally and interannually modulated by the storage and release of fresh water from the upstream Hudson Bay and that this can be explained in terms of Ekman convergence and divergence acting over the larger Bay. On shorter timescales, we found that a considerable fraction of the freshwater transport is associated with coherent, fresh, anticyclonic eddies embedded in the mean flow. Model results and analysis of the historical data indicates that these eddies are associated with the periodic release of fresh water from Hudson Bay as a result of transiting storms. A comparison of the tidal energy flux from the moorings and from a global tidal model yielded inconclusive results likely due to the limited resolution of the tidal model, and the study of the mixing driven by tides in the region is ongoing.

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Results

The moored data showed that the fresh water plume exhibits a strong seasonal signal, with the bulk of the fresh water exported in the fall, and pronounced variability on time scales of about a week. Using the high resolution regional model, we were able to show that the seasonal (and interannual) variability is primarily driven by the storage and release of fresh water in the upstream Hudson Bay and that this process is primarily regulated by the wind-stress curl over the region (St Laurent et al. in press, Figure 1). The fresh pulses which give rise to the weekly variability were, on the other hand, identified as fresh anticyclonic eddies embedded in the mean outflow from Hudson Strait (Figure 2). These eddies are generated from the periodic ejection of fresh water from Hudson Bay following the passage of storms across Hudson Bay (Sutherland et al. in press). A paper summarizing the variability on subtidal to interannual time scales is in preparation and we plan to submit it by the end of 2011 (Straneo et al.). Finally, the comparison of the tidal fluxes from the moorings and the tide model yielded inconclusive results which we principally attribute to the low resolution of the tidal model in the Hudson Bay region. At the same time, the analysis of the impact of ice on baroclinic tide generation and propagation, and the study of the strong bottom boundary layer observed in Hudson Strait and other datasets will continue as part of other ONR-funded programs (L. Rainville).

Impact for Science

Our results indicate that the export of fresh water from the Arctic to the lower latitudes occurs in highly variable currents and eddies whose variability is strongly influenced by the regional wind forcing. These findings are in contrast of the accepted paradigm of freshwater export in a continuous, mostly steady current. The discovery of fresh, anticyclonic eddies embedded in the flow is a novel result and one that has important implications for the stratification, ecosystem and impact of fresh water downstream. Also, our result indicate that like the Beaufort Gyre, Hudson Bay has the potential to store and release freshwater on interannual time scales.

Relationships to Other Programs

The processes described above are relevant to the studies of Arctic fresh water export (ASOF) and Arctic fresh water storage – including the recently initiated ONR program on the dynamics of the Marginal Ice Zone.

References

Sutherland, D.A., F. Straneo, S. Lentz, 2011: Observations of fresh, anticyclonic eddies in the Hudson Strait outflow. *Journal of Marine Systems,* special issue on Hudson Bay, in press.

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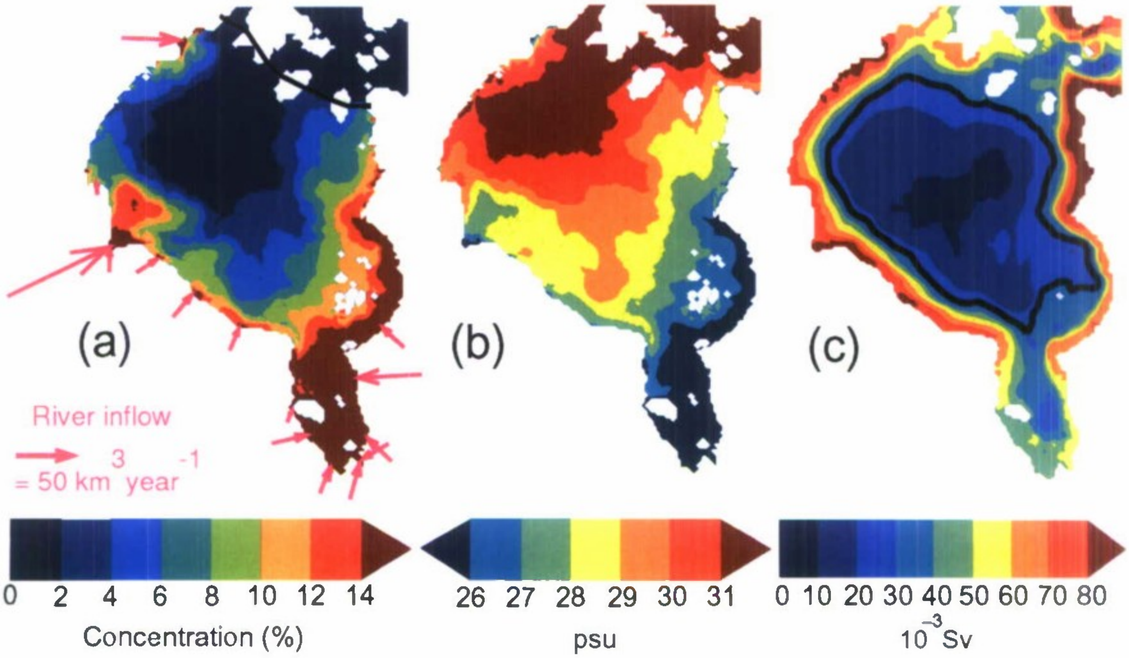

Figure 1 – Fresh river water spreading into Hudson Bay and feeding the Hudson Strait outflow from a regional numerical model. a) Spatial distribution of river tracer in summer. The black lines delimitate the extent of the tracer experiment and the arrows show the location and mean discharge of the rivers. b) simulated sea surface salinity in summer. c) Streamfunction for the mean surface currents. (From St. Laurent et al.)

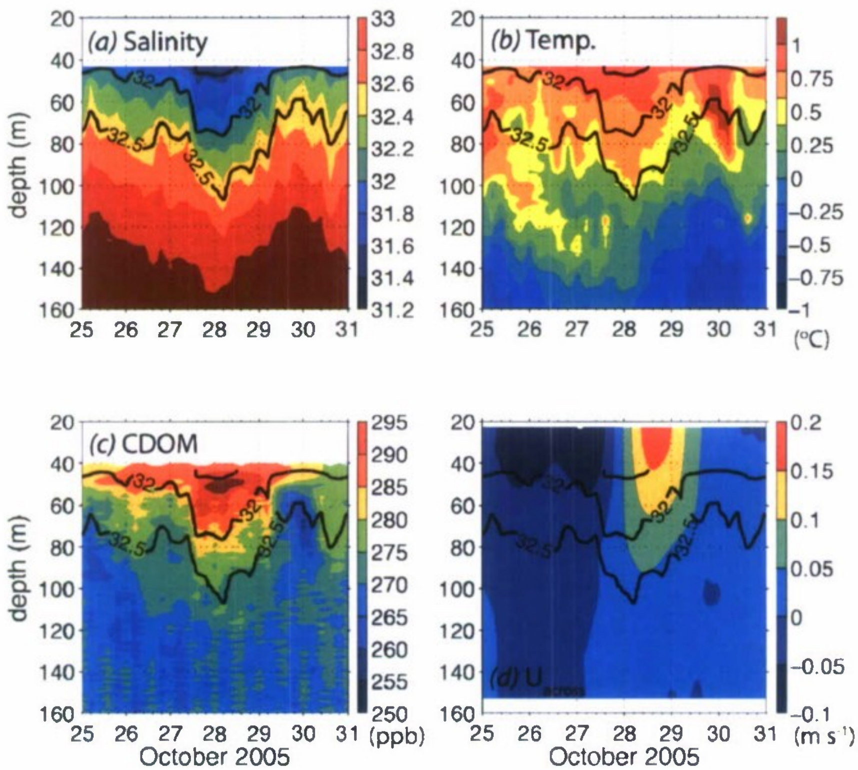

Figure 2. Fresh anticyclones embedded in the Hudson Strait Outflow. (*a*) Observed salinity record from the moored profiler (MMP) in the center of the Hudson Strait outflow during a typical low salinity event associated with a passing fresh, anticyclonic eddy. Select isohalines (black lines: 31.5, 32, 32.5) are indicated similarly across all panels. (*b*) Same as in *a*, but for the observed temperature record from the MMP. (*c*) Same as in *a*, but for the observed CDOM record from the MMP fluorometer. (*d*) Across-strait velocity ($U_{across} < 0$ is onshore) for the same time period as in *a-c*, from the ADCP. (From Sutherland et al.)